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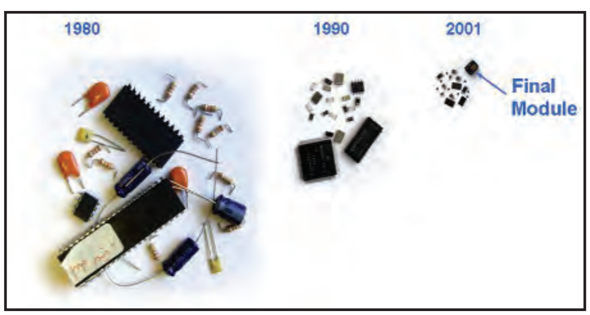
Getting PCBs Really Clean

By P.J.Duchi, Anne-Marie Laugt, Marie Verdier, Inventec Performance Chemicals, Bry sur Marne, France

Yesterday's chemicals — CFCs, HCFCs, brominated solvents, detergents and glycols — cannot do a good cleaning job on today's electronics because most flux formulations have changed. Cleaning should be adapted to the job's requirements while maintaining stability in time, efficiency, quality and performance. The world of cleaning is composed of two parts: organics and inorganics. Cleaning performance is affected by three main criteria. The first involves the solvency power of a product also known as the Kauri Butanol Index (KB Index). The second is surface tension, expressed in mN/m. This parameter must be considered because when the cleaning product cannot make contact with the contaminants under or around components, the contaminants cannot be dissolved. The third criterion consists of such physical parameters as temperature, mechanical activity, and the duration of the process.

Proper cleaning wisdom manages all of these parameters while dealing with such high-tech challenges as ultra-miniaturization and environmental care issues, that include RoHS and REACH. This wisdom of cleaning should always bring innovation to the cleaning process in electronics.



As components get smaller and smaller, it becomes more difficult to clean under them after reflow.

Miniaturization

Today's miniaturization has taken our industry a hundred light years beyond what was common in the 1980s. Today's component size is down to 0.1mm — just a dot on your metric ruler, possibly the size of a period on this page. The reliability of these components must always be maintained — miniaturization should not become a source of instability and unreliability. To achieve this, the PCB assembly's cleanliness should be pass all required tests to meet the product's specifications.

Contaminants

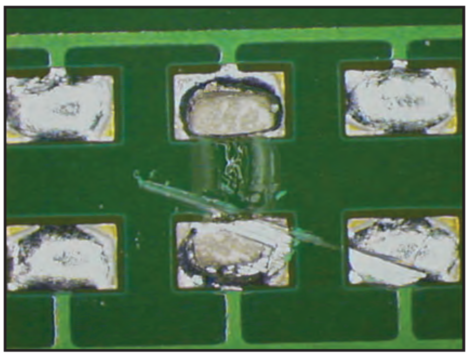
The contaminants on a circuit board are mainly composed of organics such as natural and/or synthetic resins, ions, acids, solder balls, fingerprints, and particulates of PCBs. Because lead-free alloys require higher soldering temperatures than the standard Sn/Pb, there are significant changes in the fluxes and solder pastes that are used.

These fluxes are for the most part more active and must respond properly to higher reflow temperatures. They present more risks than the ones formerly used, and the temptation is high to choose production parameters that produce shiny solder pads. The ionic cleaning of the PCBs thus becomes more critical than ever before, but these cleaning requirements will also influence the assembly process that precedes the cleaning. The ionic contamination is a good quality indicator for the long-term reliability.

Every end user has his own specifications which depend on his own production needs, or those of his customers. For this study, the PCBs for trials were produced in large quantities to triple the cleaning results. Each trial contains 30 components. All residues must disappear, including the contaminants under the components. No fingerprint, particle nor mote of dust should remain; and there should be no residues of cleaning products. The components, the resins, the underfill and the substrate should not be damaged by the cleaning process. The parts should be dried at the end of the washing step, and the ink markings should be unaffected by the cleaning.

Cleaning Products Available

The most important part of the job is to remember which chemical families are available in the market. The cleaning products available can be classified in six different families: detergents, light petroleum distillates, formulated hydrocarbons, brominated solvents, glycols and fluorinated solvents.



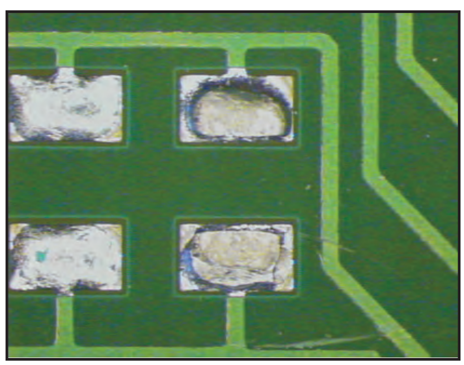
Cleaned without ultrasound.

Detergents are good most of the time, but are very specific to the type of fluxes to be removed. The detergent's concentration is very important in water and can vary between 3 to 50 percent in some cases. The temperature can vary from 20 to 60°C, and the agitation used, sprays, spray under immersion or ultrasonics should be considered. In general terms, this is called the aqueous cleaning process. The drawbacks of these detergents: the incomplete removal of all residues under components because of the poor/high surface tension between 40-50mN/m; the aggression of these formulations and compatibility with materials becomes another issue; and the rinsing with tap or DI water (high surface tension 70-80mN/m), the drying operation, the water-proof compatibility and the disposal of used (contaminated) water and solvent. The total cost of all of these factors should also be considered.

The petroleum distillates such as alcohols and ketones are mainly used for the cold cleaning operation, even though they can be found being used at warm temperatures. These products are very flammable at room temperature (20°C) and when used under warmer conditions, can become very risky. Costs are acceptable, but disposal and annual cost can be significant.

Formulated hydrocarbons were developed after the CFCs and HCFCs passed out of vogue. When perfectly formulated, they easily outperform any other cleaner. They are able to remove flux residues, solid residues and salts under any type of components because of their very low surface tension (approx. 20mN/m). However, as with the aqueous process, the same detergent drawbacks exist, whereas, with the co-solvent process, the PCBs are very nicely rinsed and dried with the vapor phase fluorinated solvents. The rinsing solvent can be recycled by distillation and the formulated hydrocarbon is easily disposed of. The formulated hydrocarbons have a very extensive lifetime and because of this, the total costs are the lowest of all types of cleaning systems. The surface tension of both formulated hydrocarbons and fluorinated solvents is outstanding. This combination is one of the most user- and environmentally-friendly processes.

Brominated solvent formulations are very simple to use in a vapor phase degreaser. Nevertheless, there are some non-solvency problems and compatibility issues. For this reason, compatibility tests must be performed with all materials in contact. Due to the very low surface tension (20-30mN/m), the ions might not be totally removed and prevent the results from matching ionic specifications. The costs are reasonably low, but the hazardous aspects for end-users and the environment are of great concern. These products are severely restricted in Europe.



Cleaned with ultrasound.

Glycols or modified alcohol formulations are used the same way as the formulated hydrocarbons with some surface tension between 25 and 35 mN/m. Unless used in a formulation, glycols can not dissolve all contaminants. In most cases, these formulations have a good solvency power, but the disadvantages of these products are the need for rinsing with tap or DI water — high surface tension, the drying operation, the waterproof compatibility and the need for disposal of the used mixture. The total cost of these elements combined is considered to be high.

Fluorinated solvents. When used pure, fluorinated solvents and formulations can not dissolve all contaminants. Even with the lowest surface tension of all families, approx. 8-15 mN/m, their solvency power is weak. But when combined with formulated hydrocarbons, then the co-solvent process is excellent for handling the toughest cleaning jobs. These products should be used in the latest solvent vapor degreasers. The solvency power is the simplest way to express the ability to dissolve the contaminants. The approved method is to use the Hansen Solubility parameters which will define for any product, parameters of molecular bonding. While this is true for theoretical calculations, when real-world products are blended, the Kauri-Butanol method establishes a direct rosin solvency value

Surface Tension

Understanding surface tension is key to understanding a good cleaning performance. It becomes especially important as miniaturization makes parts as small as the contaminant particles themselves. The smaller the parts become, the lower the surface tension of the cleaners should be. When this law is understood and obeyed, half of the cleaning is achieved.

Consider demineralized water which has a surface tension of about 80mN/m. The surface tension line bends as a function of an increase in temperature of the bath. The variation is of about -10 mN/m. This is the reason why cleaners are warmed up in washing units — to reduce the surface tension and allow the liquid to move underneath cavities and components. There is the same issue with tap water, where its surface tension starts at 70mN/m at room temperature. When detergents are added to water, the surface tension of the medium drops down to 45-35 mN/m, according to the temperature of the bath. However, the big question remains, how can a "wetting product" be rinsed with some water which has a higher surface tension? For this reason many suppliers use additives or simple isopropanol, to better rinse, wet and dry parts.

To get underneath the components, glycols or formulated hydrocarbons are commonly used. Their surface tensions are lower than water and detergents, between 25-35 mN/m for the glycols and around 20mN/m for the formulated hydrocarbons. The same rinsing problem remains for these products with water, so it is preferable to use a selected final rinsing solvent which has a lower surface tension than these cleaners and which will finally dry the PCBs.

As solvents evaporate and condense on the free-boards of the vapor phase equipment, no residues are left on the PCBs and the surfaces, including under the components.

Mechanical Agitation

There are many types of mechanical agitation that can be used — sprays, sprays under immersion, ultrasonics, agitators, rotation, and others. Agitation provides an additional cleaning parameter which helps to penetrate, to dissolve and to unfasten contaminants. This study evaluates all types of mechanical agitation and compares their efficacy. Many times, industrial PCB assemblers avoid using ultrasonics because of some fear about damaging the components, particularly, quartz. The trials, which included 60 different assemblies containing quartz crystals — accordingly to Norm IPC-TM-650 — have demonstrated that none of the crystals have been affected or damaged in any way. The benefits of ultrasonics were easily determined.

This cleaning study shows that there are many parameters that affect cleaning efficiency. The final aspects and performances of these PCBs are based on the mastering of cleaners, size of the assemblies, agitations and the cleaning processes.

When the choice is based on solvency power, the lowest surface tension and the most efficient process, then a perfect job can be reached matching the toughest specifications. The co-solvent/Vapor degreaser process with formulated hydrocarbon and HFE (hydrofluoroether), combined with ultrasonics or jets show the best performance. Contamination is below 0.2µg of Eq NaCl/cm^2 for ranking 9 (on a scale of 1 to 10) and with a perfect visual aspect under components. No damage of quartz could be found in any of the trials.

Cleaning process	Product Family	Equipment type	Comparative 1:10 best
Aspersion, aqueous	Detergent 1	Dish washer type	4
Immersion US 40 kHz, aqueous	Detergent 2	Sumps in line	1
Immersion jets, semi-aqueous	Glycol formulation 3	Sumps in line	3
Immersion US 40 kHz, semi-aqueous	Glycol formulation 3	Sumps in line	7
Immersion US 30 kHz, mono-product	Glycol formulation 4	Vacuum machine	7
Immersion US 40 kHz, semi-aqueous	Glycol formulation 5	Sumps in line	1
Immersion, co-solvent mixed	Form hydrocar/HFE	Vapor degreaser	4
Immersion, co-solvent mixed	Form.hydrocar70/HFE	Vapor degreaser	2
Immersion US 25 kHz, co-solvent sep	Form hydrocar/HFE	Co-solvent/vapour degreaser	9
Immersion US 38 kHz, co-solvent sep	Form hydrocar /HFE	Co-solvent/ vapour degreaser	9
Immersion Jets, co-solvent separated	Form hydrocar./HFE	Co-solvent/vapour degreaser	8
Immersion US 40 kHz, vapour phase	Brominated solvent	Vapour phase	4

Comparative results of different cleaning processes.

Contact: Inventec Performance Chemicals, 26 avenue du Petit Parc, 94683 Vincennes Cedex, France
☎ 33 (0)1 43 98 75 00
fax: 33 (0)1 43 98 21 51
Web: www.inventec.dehon.com ❐